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CONTENTS

Some Recent Speculations on the Nature of Light: PROFESSOR EDWIN B. WILSON 265

The Conception of a Species: DR. C. C. HURST 271

International Critical Tables: DR. VERNON KELLOGG 273

Scientific Events:

Excursion of the International Soil Science Congress; The Scientific Division Committee of the United States Fisheries Association; Fellows of the Royal Society of Edinburgh; National Research Fellowships in the Biological Sciences 273

Scientific Notes and News 275

University and Educational Notes 279

Discussion and Correspondence:

The Color of Hydrated Silica and Alumina: DR. P. G. NUTTING. *A Criterion for distinguishing Identical Twins from Fraternal Twins:* PROFESSOR TAKU KOMAI. *The "Tearing Method":* DR. LECOMTE DU NOÜY. *Study of Bartlett Pear Blackend undertaken in California:* M. J. HEPPNER 279

Scientific Books:

McAdie's Man and Weather: DR. BURTON M. VARNEY. *Nomenclator Animalium Generum et Subgenerum:* DR. WALTER LANDAUER 281

Special Articles:

The Influence of Selective and General Irradiation by a Quartz Mercury Arc Lamp upon the Germination and Growth of Seeds: DR. CHARLES SHEARD and GEORGE M. HIGGINS. *The Effect of Sodium Bicarbonate on the Titration of Iodine with Thiosulfate:* O. E. SCHUPP, JR. 282

Science News x

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SOME RECENT SPECULATIONS ON THE NATURE OF LIGHT[1]

FOUR weeks, one day and four hours ago I was sitting on a sofa in the Cosmos Club, Washington, chatting with your distinguished director during a brief interval between long committee meetings. That was when, but I know not just how or why, I was caught by that wily hunter for this particular repast. This time he was not after big game—merely angling for a poor fish.

There is no need to import any outsider into the Jefferson Physical Laboratory to talk about light. Here you have Pierce with his wave lengths in hundreds of meters and Duane with them in fractions angstroms, a range of 10^{14}. Here the celebrated Lyman region was found and explored. You have in Saunders one who has followed series spectra from Ritz to Bohr and beyond. Then there is infra-red Kemble and band-spectra Mulliken, and for recent speculations on the nature of light why look further than Slater? The whole range of factual and deductive and speculative optics is here, and nowhere else in greater variety or completeness or perfection. If Count Rumford were alive he would perhaps feel that you were all out for the Marathon that leads to his medal and premium—and all likely to win.

The count spoke of light and heat. To-day light and heat and electricity have come together. Therein lies our difficulty and thence issue our speculations. While light stood alone we had reached a satisfactory theory of its nature as a wave motion in a medium. When it passed to heat and we became interested not in the transparent but in the black body we were in trouble at the short end of the spectrum and that trouble has been confirmed and accentuated by photoelectric phenomena. A score of years ago Ritz[2] in a masterly critique of electromagnetic theory suggested strongly that the time had come when it might be no longer useful and might perhaps even be harmful to consider energy as localized. We have proceeded, in the most contrary way, to emphasize more and more the localization of energy, especially radiant energy, and to endow this energy with momentum, angular momentum, with mass, inertia and weight. The quantum theory and the Bohr orbit have certainly been

[1] An address before the Physical Colloquium, Jefferson Physical Laboratory, May 24, 1926.

[2] W. Ritz, "Gesammelte Werke."

increasingly with us, and are likely to remain for some time.

Perplexing as our situation is, we should be happy in it. For it is wholesome, healthy and young. We have become again as little children to whom everything is new and wonderful, and we are learning facts so fast that their systematization is not to be expected. In due time we shall come again to a period of senility in which we shall understand and no longer learn. It will be some precocious, maybe I had better say some prematurely senile young man from whom will issue this virus of sclerosis.

An Interpretation

Light came into the world on the first day, and it was good. Sight is our best sense. To see is a synonym, not even colloquial, for to understand. A dog would say, "Do you *smell* that?" Optics is one of our oldest sciences. For long times there was dispute as to whether light issued from the perceived object into the eye or emanated from the eye to the object seen. It has remained till the year 1925 and to G. N. Lewis[3] to suggest that the eye and the object are in contact and that the relation is mutual. Let us examine this speculation of Lewis's. Einstein interpreted the Lorentz transportation as relativity, not the relativity of Newton nor of the later Einstein, but the special relativity of electromagnetic theory. Minkowski gave an elegant mathematical formulation of this relativity which Lewis and I elaborated in 1910–1912 and printed in the latter year in the *Proceedings of the American Academy*. One may say that fundamentally neither space nor time are of separate physical significance, they are individually anthropomorphic, if not conceited, conceptions based on the notion that the individual observer is at rest, probably at the center of the universe, and everything else in motion. Physically the important thing is the local time, the Eigenzeit, $d\tau = \sqrt{c^2dt^2 - ds^2}$, a fusion of space and time. Along the path of light $d\tau = 0$, and there is no lapse of space-time; a particle moving with velocity less than that of light has a past and future defined by its space-time path, but not so for light itself. Hence, says Lewis, we make the interpretation that there is contact between the perceiving eye and the object perceived and more generally between any two objects in radiative interchange. To some this sounds bizarre if not impish.

Let us for a moment consider what is the function of mathematical physics. In a certain sense we get out of mathematical physics only what we put in. This is a purely mathematical implication and means merely that if our mathematics is water-tight every conclusion must follow deductively from the premises. But in another and more physical sense we may and we ordinarily do hold that when we interpret our mathematical conclusion as a fact of nature we get new physics. In this way Hamilton got conical refraction, and it was a sound way to get it provided that observation verified deduction. Suppose observation had belied deduction. Then we should have been forced to conclude not that the demonstration was in error but that the premises on which it was based were inadequate for, or contained elements extraneous to the theory of light, or were contradictory within themselves; *i.e.*, they were logically inconsistent or inconsistent with nature. Many other instances of obtaining from mathematics new physics could be adduced, and also many, perhaps more, instances of obtaining too much or too little. It is the interpretations that determine the value of mathematical physics and that make it as Darwin pointed out in 1912 a more exacting science than pure mathematics. Now Lewis has made an interpretation. It is a reasonable interpretation of the mathematics fundamental to relativity. Without prejudicing the mutuality of the relationship of contact, I may be permitted to say anthropomorphically that the interpretation can not fail to throw light upon the subject.

An Adaptation

For a long time there was a dispute as to whether light moved faster in the optically denser medium or more slowly. On the corpuscular theory it was believed that the potential energy was constant in each uniform isotopic medium but changed in the interface, *i.e.*, that the normal component of the velocity of light changed across the interface but the horizontal component remained the same. This led to the view that the velocity was greater in the denser medium—for such an interpretation is forced by the law of refraction. Moreover, this theory may be supported by the law of stationary or varying action. It is only necessary to take the law in the form[4] $\delta \int v\,ds = 0$ with $v = nc$, where c is the velocity of light and n is the index of refraction, to obtain the proper relation $\delta \int n\,ds = 0$ of geometrical optics. On the other hand the wave theory leads to the conclusion that the velocity is less in the denser medium, and this view was early urged by Fermat in connection with his principle of least time. Here we have $\delta \int ds/v = 0$, but $v = c/n$ and hence again $\delta \int n\,ds = 0$. The question of velocity as a physical fact was settled experimen-

[3] G. N. Lewis, Silliman Lectures, Yale University and Proc. Nat. Acad Sci., 12, p. 22.

[4] W. R. Hamilton, Trans. Irish Acad., 15 (1924), p. 69. See also H. A. Lorentz on Light, Encyc. Brit., Vol. 16, p. 618.

tally by Foucault and would in any case have been assumed as settled by the triumph of the wave theory even if the experiment had not been forthcoming at a time proper to the support of the theory. The equation $\delta \int n\,ds = 0$ remains and the principle of least action must be adapted thereto with the condition $v = c/n$ instead of $v = nc$.

As is usual in such cases the adaptation may be made in a number of ways. The most recent and perhaps the neatest is that due in 1925 to Cox and Hubbard.[5] They assume that a beam of light is made up of quanta $h\nu$, that the number of these quanta in the incident beam is equal to the sum of the numbers in the reflected and refracted beams, which is equivalent to assuming the constancy of energy. The momentum in vacuo associated with a quantum $h\nu$ is $h\nu/c$ and the authors assume that in a medium of index $n = c/v$ the momentum will be $h\nu/v$, so that a quantum has a greater momentum in the denser medium where it has the smaller velocity. This checks with our notions on the basis of the wave theory. If we define the element of action for the quantum as the product of the momentum $h\nu/v$ by the element of distance ds we have in the equation $\delta \int (h\nu/v.ds) = 0$ the principle of least action so adapted as to give the correct equation $\delta \int n\,ds = 0$ from which the laws of reflection and refraction flow. It should be remarked that in this theory we are dealing with large numbers of quanta. It would seem as though individual quanta must be either refracted whole or reflected whole. The constitution of the medium must therefore determine, and through its index of refraction specify, what fraction of a large number of quanta, *i.e.*, what is the chance that any one quantum, incident at a given angle, shall be refracted or reflected.

AN ABSTRACTION

Maxwell gave us an electromagnetic wave theory of light. Gibbs gave us an electrical theory.[6] These amount to the same thing if all magnetism is generated by the motion of electricity. But the method of Gibbs is totally different from the method of Maxwell; it is a real contribution, and though scarcely recent seems never to have made an impression on optics and hence is worth mentioning. He likened a transparent body to an area of marine piling and light to a ground-swell moving towards and through it. The piles will not affect the ground-swell much as a whole, there will still be an advancing periodic motion of the original frequency though of diminished wave length. But superposed upon that will be an irregular motion. Gibbs set himself the problem of calculating the part of the energy that would be found in the regular and the part that would be found in the irregular motion —not of course for the two-dimensional analogon of the area of piling, but for the transparent body and the light. On these very general assumptions of a fine-grained structure for his medium, of some general properties of simple harmonic waves and of a few basic principles of electrodynamic action he was able to explain the behavior of transparent bodies, including those optically active, and by a familiar analytical device using complex numbers further to extend the equations to absorbing media. I would emphasize the uselessness of special hypothesis for so much of optical theory as is derivable from abstract generalities. How this work would be adapted to the theory of quanta is not easy to see; before we get quanta fully adapted to the type of optical phenomena with which he and the older physicists were concerned such difficulties may be resolvable.

A PICTURE

Maxwell built his theory of electromagnetism on the work of Faraday with a good training, which Faraday did not have, in the work of Green and Stokes and other workers with continuous media. It is not easy to understand Maxwell in all places, one may even doubt if he fully understood himself. Kelvin never completely went over to him. Perhaps Heaviside was our only complete Maxwellian, more complete than his original. Presumably Maxwell attributed little physical reality to the Faraday lines of force; it would be unnatural for a student steeped in hydromechanics and the theory of elasticity to do so. J. J. Thomson has tended to return to Faraday and treat the lines or tubes of force as real and atomic. Writing in 1903 he said:[7]

> This view of light as due to the tremors in tightly stretched Faraday tubes . . . discrete threads embedded in a continuous ether, giving to the latter a fibrous structure . . . , on this view, then a wave of light itself must have structure, and the front of the wave instead of being, as it were, uniformly illuminated, will be represented by a series of bright specks on a dark ground, the bright specks corresponding to the places where the Faraday tubes cut the wave front.

And he went on to use this picture to explain the small amount of ionization produced by light. As a Faraday tube must start and end on electric charges, these charges must be separated by the wave front. This implies a separation of charge for which I have

[5] Cox and Hubbard, Proc. Nat. Acad. Sci., 11, p. 498.

[6] J. W. Gibbs, "Scientific Papers," Vol. 2.

[7] J. J. Thomson, Silliman Lectures, Yale University, published as "Electricity and Matter," p. 62.

never seen any physical evidence, unless we get around the difficulty by assuming that the Faraday tubes are in pairs, about one half running from negative electricity behind the wave to positive ahead of it, the other half from positive behind to negative ahead. If we can get around the difficulty of charge, there is a remarkable similarity between Thomson's suggestion of 1903 and Lewis's of 1925—the emitter and recipient electrons are in connection *via* a Faraday tube which is a light-path and from the viewpoint of relativity may be said to be in contact.

Similar as the two suggestions are, I can not see that Thomson's of 1903 has any similarity to Thomson's[8] of 1924, and I must confess to having had that difficulty before with some of Thomson's papers separated by an interval much shorter than twenty-one years. At any rate he appears to consider that there is some continuity between the papers because we find in that of 1924 a brief extract in quotation marks from the earlier paper. The Faraday tube is of course still with us, but so far as I can determine the tightly stretched strings whose tremors constitute light and which cut the wave front in the bright specks have quite disappeared. What the Faraday tube now does is to stay in the atom, but occasionally to get snarled up and throw off the snarls as light corpuscles. Let us quote Thomson: "The mutual potential energy of an electron E and a positive charge P is located in the tube of force stretching between E and P. If the electron falls from E to E′ this potential energy is diminished by the energy in the portion EE′ of this tube of force. During the approach of E to P the tube may be thrown in a loop, the closed part of the loop gets detached and goes off as a closed ring which rapidly becomes circular and travels with the velocity of light in a direction at right angles to its plane like a circular vortex ring." The process of absorption is the reverse—one of these rings gets foul of the Faraday tube in an atom in such a peculiar way that it reunites with the tube and pushes the electron out to a more distant orbit.

PSYCHICS

It appears as though the Faraday tube were a very obliging if not changeable fellow. To his tension, at one time, is due the tendency of positive and negative charge to get together, but now the electron under some circumstances can move in so fast that his tube can not follow and gets looped. And though in the process of getting looped a tube must apparently travel largely in its own plane, once it snaps off its loop the latter moves perpendicular to its plane and with the velocity of light despite the fact that previously it had not been able to keep up with an electron. The leopard has changed his spots. We need not insist upon sense in such matters. Bohr has written that an electron does not know it is in a stationary state until it has been around the orbit a few times.[9] This is humanly intelligible, it is sound behaviorism. All we need now is to have some physicist who has read up the new psychology as a minor tell us that the Faraday tube that draws the negative and positive electricity together is but a gross materialization of the real fundamental force of nature, the sex instinct, and our molecules have become as inhumanly lewd as we are alleged to be! There must always be mystery forces and mystical structures at the basis of physics, we can not explain except from unexplained postulates or define except in terms of the

[8] J. J. Thomson, *Phil. Mag.*, 48, p. 737; 50, p. 1181.

[9] N. Bohr, D. Kgl. Danske Vid. Sels Skrift, Nat. Math., Afd. 8, IV, Pt. I. German Translation by Hertz (pp. 28–29): Die Antwort . . . ob ein gegebener Zustand stationär ist . . . kann nicht gegeben werden, ehe die Teilchen nicht durch einen völlstandigen Zyklus von Zuständen hindurch gegangen sind und sozusagen Kenntnis vom ganzen Kraftfeld und desen Wirkung auf die Bewegung genommen haben. . . . ” It may be remarked that the quantum theory originated with Planck in connection with an empirical equation for black body radiation and that in the first edition of his Wärmestrahlung he proves the formula from the Maxwell theory and classical mechanics. Later Poincaré showed that the conclusions were inconsistent with the premises and in subsequent editions of his book Planck suppressed the proof in question and substituted a quasi-axiomatic procedure. Bohr's work and its elaboration into an astounding detail by him and others was based on a combination between dynamics of a particle (central forces) and the quantum conditions. Lapsing into a psychological mode of expression is no retraction of accomplishments but an indication of perplexity as to the future; it is only in the most recent months that we are learning from Born and Heisenberg how to set up the quantum theory on its own feet independent of classical mechanics or electromagnetics and in a way which if successful may lead, as implied in the text, to a redefinition of fundamental concepts in terms of it.

[Note added in proof. Another hopeful formulation of the quantum theory on its own feet, which was appearing as this lecture was in preparation, is Schrödinger's undulatory theory of mechanics, now available in *Physical Review*, Vol. 28, 1926, pp. 1049–1070, and apparently largely transformable into the system of Born and Heisenberg, but inspired by the contributions of de Broglie mentioned in the final paragraph and by the optical investigations of Hamilton cited above, ref. 4. The Bohr orbits seem to have gone and to be superseded by structure represented by vibrational types in a distributed charge, a suggestion which in different mathematical guise was put forward long ago, I think by J. J. Thomson.]

undefined. It may be an advantage to have our primitive propositions and undefined symbols translated into graphic language.

I shall pass over the quantum theory itself as a recent speculation on the nature of light. It is both too well and too little known to require mention. But I should perhaps say a word about the two-electron jumps of Saunders and Russell,[10] be it only to ask how soon we shall find three-electron or four-electron jumps. The two-electron jump seems to me almost too much of a good thing for the good simple old quantum theory. We shall soon have to add to the conception of the electron's nose for its home some sort of supernormal telepathic intercourse with other electrons. Certainly many of the mathematical relations which are now attached to the quantum theory have come to stay just as has the sine-law of refraction; but it was long after the discovery of that law that we knew whether the velocity of light was greater or less in the denser medium and we do not yet know whether light is a wave motion or corpuscular or how divided between the two. The orbit picture of the atom may disappear and be replaced by structure. So long as our notions of action remain as indefinite in a physical sense as they still are we shall be loth to constrain motion by quantum conditions based on action. The way out may be to get a keener appreciation of action itself and to replace conceptions now taken as primitive by definitions of them in terms of action. We used to write $\Delta E = h\nu$, we now write $\nu = \Delta E/h$ and the frequencies are not orbital frequencies. The question appears no longer to be why is $\Delta E = h\nu$ but how should $\nu = \Delta E/h$? Is frequency a temporal phenomenon at all? It is not the arithmetic but the interpretation of this equation which is physics.

THOMSON'S CORPUSCLE

Let us return to the light corpuscle of Thomson. The energy of the ring may be calculated. If f is the electric polarization the energy is $E = 2\pi f^2 \times$ the volume of the ring which is $2\pi r \pi b^2$ if r be the radius of the ring and b that of its generating circle. But the total amount of electricity represented by the tube in the loop can not exceed e, and $f\pi b^2 = pe$ where $p \leqq 1$. Hence $E = 8\pi^2\ p^2e^2\ (r/b)^2\ (1/2\pi r)$. We assume that the rings are similar so that the energy varies inversely as the radius. The introduction of the facultative fraction p jars on the picture. Apparently there may be several Faraday tubes from a single electron, possibly of varying electric equivalents, of which only one or some become looped and shuck off a light-corpuscle. We next assume that the frequency of light associated with the ring is $\nu = c/2\pi r$, which means that the wave length is the circumference of the ring. Then $E = 6.2 \times 10^{-28}\ (p\,r/b)^2.\nu$ and we have Planck's $E = h\nu$ provided $pr/b = \pi$ or something very near to π. If $p = 1$ and $r/b = \pi$ the corpuscle makes a good commercial doughnut. For visible light of 6,280 angstroms, $r = 1000$ angstroms $= 10^{-5}$ cm. and the doughnut has a volume of $2\pi r \times \pi b^2 = 2r^3 = 2 \times 10^{-15}$ cm.^{3} The volume held by an atom is of the order of magnitude 10^{-23} cm. and the doughnut would contain 50,000,000 atoms. Somewhere I have seen it stated that a quantum of visible light is supposed to engulf a great many atoms, though it materially affects very few. Of course if we take p as a small fraction, the ring becomes like a child's hoop and will cover fewer atoms in proportion to p^2 but then we must have many Faraday tubes of which only one may get kinked. If we go down to X-rays of wave length $10^{-8} = 2\pi r$ the volume of the ring is $10^{-24}p^2/4\pi^3$ and is much less than that of an atom.

Thomson follows out the consequences of this corpuscular model and makes out a case for its satisfactory explanation of a goodly number of known experimental facts. We shall not follow the details. One characteristic of his theory of the nature of light is that it is dual. We have these corpuscles and we have ordinary Maxwellian waves like the Hertzian wireless waves. Some of the emission is corpuscular, some is ordinary. The fraction of the emitted energy which appears in the one or the other form depends on circumstances and on wave length. The corpuscles are accompanied by an aura or embedded in an umbra of old-fashioned waves which even in the case where the waves have but little of the energy serve to direct or guide the corpuscles and thus determine phenomena like diffraction and interference. This seems to me somewhat to smell of trigger-action which has recently been much in disgrace but with a dreadful social callousness insists on showing up again—for instance, in Bohr's electron sniffing about its tracks to determine whether it is at last home in a stationary state or off on another false scent. My belief is that trigger-action like mystery forces will long be with us. The amount it is allowed to disport itself in public is a measure of our lack of confidence as to where we are at.

WHITTAKER'S MAGNETON

In a recent paper Whittaker proposed a model to explain some photoelectric phenomena. It was a magnetic model, a sort of magneton. I presented this work a while ago to the staff seminar of this department on a Monday evening and it was howled down. I rather liked the model—it was so definite, but I

[10] Saunders and Russell, *Physical Rev.*, 22, p. 201.

shall not revert to it. Now Whittaker[11] comes to Thomson's aid with a demonstration that the ring corpuscle is possible on the basis of Maxwell's equations so modified as to include magnetic current after the manner suggested by Heaviside. These equations are (in the absence of electric charge)

$$\Delta \cdot \mathbf{E} = 0,\ \Delta \times \mathbf{H} = \dot{\mathbf{E}}/c,\ \Delta \cdot \mathbf{H} = \mu,$$
$$-\Delta \times \mathbf{E} = \dot{\mathbf{H}}/c + \mu \mathbf{v}/c,$$

when we allow for permanent magnetism μ and its connection current $\mu \mathbf{v}/c$. (We could use $\Delta \cdot \mathbf{E} = \varrho$ and $\Delta \times \mathbf{H} = \dot{\mathbf{E}}/c + \varrho \mathbf{v}/c$ if we wished to get in the charge.) There is also the expression $\mathbf{F} = \mathbf{H} - \mathbf{v} \times \mathbf{E}/c$ for the mechanical force acting on the magnetism. If we write

$$E_x = H_x = 0,\ E_y = H_z = -z\,(a-r)\,f\,(x-ct),$$
$$E_z = -H_y = y(a-r)\,f\,(x-ct) \quad r > a$$
$$E_x = E_y = E_z = 0,$$
$$H_x = H_y = H_z = 0 \quad r > a$$
$$\mu = -(2a-3r)\,f\,(x-ct),\ r < a, \qquad \mu = 0, \qquad r > a,$$

we have a solution of the extended Maxwell equations which makes $\mathbf{F} = 0$ so that the solution does not suffer distortion. This does not give an annulus but is circularly symmetric about the line of motion which is the x-axis. The total free magnetism is zero. (Note that if we have a closed line of magnetic force we have electric current passing through the circuit and that the ring corpuscles have closed lines of electric force which should imply magnetic current through the circuit. By the circuit is here meant the cross-section of the annulus in its plane.)

So far as I can see the factor a–r may be replaced by any function $\varphi(r)$ provided the appropriate change in the expression for μ be made, namely, $\mu = -(2\varphi + r\varphi')\,f\,(x-ct)$. The factor $f\,(x-ct)$ ensures propagation with velocity c along the x-axis. The velocity v (above) is here put equal to c, the velocity of the pulse. This is apparently an ether theory with the velocity v measured relative to the fixed ether. Whittaker points out that the magnetism allows magnetic force or electric current to grip the corpuscle and deflect it—a possibility postulated by Thomson. The corpuscle has a substantiality in excess of ordinary radiation. He refers to his earlier paper and remarks that it seems as though magnetic currents have the special function of making it possible to reconcile the quantum theory with the classical. Thomson did not postulate that the electric force on the inside and outside boundaries of his ring were zero. He speaks definitely of discontinuities in the electric force within and without the ring, whereas Whittaker has adjusted matters so that E shades off to 0 at r = 0 and r = a and the total magnetism is null.

The magneton may help in reconciling heat and light, quanta and classical theory, free propagation of radiant energy and interchange of energy between radiation and matter. It may be doubted whether it will be sufficient. There was a time when positive and negative electricity were supposed to be alike save for sign. We have known for some years that the electron and proton are very different in mass. Presumably they have other differences—perhaps one in size. Then we have the atomic nuclei. In the case of helium four protons and two electrons are supposed to cleave together in the nucleus. Ordinary interchanges between radiation and matter involve protons and electrons in addition to corpuscular light. We still have, I believe, some quantum difficulties with helium, despite the prodigious amount of ingenuity that has been spent on the matter, and possibly with the hydrogen molecule H_2 which involves two protons and two electrons. Then there is the existent, if somewhat unstable, H_3 or H_{3+}. There are still many unknowns at the kernel of physics. It is a little early to say wherein will lie the special function which shall some day reconcile quantum theory with our older conceptions.

BATEMAN'S DOUBLET

We must not overlook Bateman. His introduction of new and unexpected solutions of the Maxwell equations was mighty work. As a mathematical discovery it has not appealed to mathematicians so strongly as the finding of a new periodic solution in the problem of three bodies, but perhaps some day it will. As a physical tool it has not so much appealed to physicists as I believe it should. Bateman is probably the most powerful and consistent mathematician now working in electromagnetic theory. Sir W. H. Bragg used to maintain that the corpuscular form of radiation carried electricity with it. His original notion of a neutral pair (electron plus proton) has not found favor. I may mention that on account of the duality of electric and magnetic phenomena one could from some points of view just as well take Thomson's circular tube of electric force to be an annulus of magnetic force, and then Whittaker's solution would require not magnetic current but electric current and we should have a neutral pair associatetd with the corpuscle and moving with the velocity of light. Bateman's solution is of this sort, electromagnetically symmetric to Whittaker's; analytically it is[12]

[11] E. T. Whittaker, *Proc.* Roy. Soc. Edinburgh, 46 (1926), p. 116.

[12] H. Bateman, *Phil. Mag.*, 46 (1923), p. 977.

$$E_x = H_x = 0, \quad E_y = H_z = \frac{\partial \Omega}{\partial y} f(t - \frac{x}{c}),$$

$$E_z = -H_y = \frac{\partial \Omega}{\partial z} f(t - \frac{x}{c}),$$

where Ω is a function by y and z whose derivatives are large near some parts of the y-z-plane and small elsewhere. This gives $\nabla . \mathbf{H} = 0$ but $\nabla . \mathbf{E} = (\partial^2\Omega/\partial y^2 + \partial^2\Omega/\partial z^2)\ f\ (t - x/c)$ and thus leads to a charge wherever f does not vanish and Ω fails to satisfy Laplace's equation. The ponderomotive force vanishes. The solution is more general and earlier than Whittaker's, as the latter states. We may notice that the total charge in the pulse is zero if the average value for f on x is zero, as it will be if f is simply harmonic like $\sin(t - x/c)$, or if the plane integral of $\nabla . \nabla \Omega$ vanishes, *i.e.*, if the sum of the boundary integrals of the magnetic force is zero.

Bateman works with the special function $f(t - x/c) = f(u) = (\sin 2\pi\nu u)u$ which gives as the energy of the pulse $2\pi^2\ cW\nu$ where W is the energy in the plane of y and z, *i.e.*, $W = \int\int (\nabla \Omega)^2\ dxdy$. With $2\pi^2 cW = h$ we should get for the universal constant $W = 1.1 \times 10^{-38}$ with dimensions mass times length. If we take out the mass of the electron we have a universal constant 1.25×10^{-11} with dimensions of length, and dividing by c we have 4×10^{-22} as a universal constant of time—these correspond to a wave length of a little more than one thousandth of an Angstrom, which is about one twentieth of the wave length that on the quantum theory would be emitted if an electron at rest blew up and dissipated its energy into radiation. Presumably, however, we are not ready for such numerical speculations, fascinating and modish as they are. Another interesting point about this example is that on reflection by a plane mirror moving with velocity u we find the quantum reappearing with the same type of f but with its frequency changed as required by Doppler's principle. Now Doppler's principle is derivable from very general considerations on waves and pretty as the above demonstration is, it would be prettier to reverse it and find what restriction the principle puts on types of function f.

I have not ventured into de Broglie's light-molecules and his statistical investigations with them, nor mentioned the apparent necessity that quanta be of two kinds, right- and left-handed. I have not gone into the work of Born which he has but so recently discussed at length in his lectures at M. I. T., or the propositions of L. V. King in a pamphlet that I have not seen, or even of Barla's phenomena in X-rays, which seems to be contesting the explanation of the Compton effect. To cover all the recent speculations on the nature of light would be fairly well to cover the interesting and disputed parts of modern physics. That can not be done in an hour. Some years ago A. G. Webster in commenting at the American Academy on the difficulties we have been discussing said that the modern physicist had a perfectly good coat and an equally good pair of trousers but was completely naked between the two. It sometimes seems as though the still more recent discoveries and disputations had tended dangerously to fray out the nether part of the coat and the upper portion of the trousers. We shall sometime have a beautiful whole new suit, possibly with spats and cravat and patent leathers and a plug hat, but those will be the evil days when the grinders cease because they are few and those that look out of the windows be darkened. Let us enjoy our present gamin life.

EDWIN B. WILSON

SCHOOL OF PUBLIC HEALTH,
HARVARD UNIVERSITY

THE CONCEPTION OF A SPECIES[1]

IN the light of recent experiments and researches in genetics, cytology and taxonomy it is now possible to present a more precise conception of a species.

A species is a group of individuals of common descent with certain constant characters in common which are represented in the nucleus of each cell by constant and characteristic sets of chromosomes.

Since the discovery of Mendel's law, genetics, with its experimental analyses of hereditary units, has thrown considerable light on the nature of variation in plants and animals. It is now clear that hereditary variations are due to discontinuous mutations in the chromosomes, but it is equally certain that the most minute variations perceptible may be inherited, as demonstrated in the eye-colors of *Drosophila* and as I found in the minor flower-shades of the scarlet *Antirrhinum*. Genetics has provided us with a fairly complete understanding of the nature and inheritance of the minor variations of individuals, varieties and sub-species upon which Darwin rightly laid so much stress, and to which many modern systematists have given specific rank. Concerning the major variations that constitute species and genera in the broad Linnean sense little light can be expected from genetics alone, owing to the barriers of sterility between the larger groups.

Recently, cytology, with its modern refinements of technique, has made remarkable progress in the analyses of chromosome complexes. So far as my records go, at least 2,845 species of plants and animals, representing 1,326 genera, 417 families, 181

[1] Paper read at a joint discussion between Sections C, D and K, at the British Association, Oxford meeting, August 10, 1926.

orders, 77 classes and 33 Phyla have been examined. The chromosome numbers found in these species vary from one pair in the Nematode Worms *Gordius* and *Ascaris* to more than one hundred pairs in the Decapod *Cambarus,* while in plants the numbers range from two pairs in the Fungi *Eumycetes* to more than one hundred pairs in *Equisetum* and the ferns *Ophioglossum* and *Ceratopteris.* In all recent cases, where large numbers have been examined by several observers, it has been found that the number of chromosomes or chromosome sets is constant and characteristic for each species. In some genera the chromosome numbers of the species so far examined are identical. In other genera the chromosome numbers are polyploid, being in regular multiples of a basal number: notwithstanding the comparatively few cases where many species of a genus have been examined, fifty-four polyploid genera belonging to seven phyla have been found in plants, while in animals, where much less has been done, twenty-five polyploid genera belonging to ten phyla have been recorded. In other genera the chromosome numbers may be either in two or more polyploid series or they may be irregular. It is important, however, to emphasize the fact that visibly identical chromosome complexes may be entirely different in their genetic constitution, they may have similar genes in different combinations and arrangements or they may have entirely different genes. For this reason chromosome numbers are only of secondary importance, and cytology alone can not be expected to provide a conception of a species. It is only by an intimate combination of the experimental methods of genetics with the cytological analyses of the chromosome complexes of various species and genera that important results have come.

After the discovery of Mendel's work and its extension to various species of plants and animals by Bateson and others, the most important advance was made by Morgan and his colleagues, who have been able experimentally to locate the relative positions of the genes of the Mendelian characters of *Drosophila* in each of the four chromosomes and to establish a linkage system of these characters within each chromosome. This valuable work has now been amply confirmed in many genera of plants and animals and is being rapidly extended. These experiments by combining cytology with genetics have broken new ground and have demonstrated the chromosome mechanism by which the minor variations of a species are inherited.

The next step is to discover the chromosome mechanism which regulates the inheritance and evolution of the major variations that constitute species and genera, and many investigators are now working at this problem. This brings in taxonomy, the oldest and most important of the biological sciences, for in any conception of species the systematist must have the final word, since it is he who makes use of the results obtained by other biological specialists in order to build up his classifications, distributions and phylogenies. My own work has been chiefly concerned with an intensive study of the polymorphic and polyploid genus *Rosa.* The species and sub-species of this genus have been exhaustively analyzed taxonomically and 424 individuals of these (representing all the known species) have so far been examined cytologically, which, added to the 332 individuals previously examined by Täckholm, Blackburn and Harrison and Penland, makes a total of 756 individuals in which the chromosome complexes have been analyzed. A large number of genetic crosses have been made between the various species and a number of F_1 plants raised, which, though sexually sterile, have provided valuable material for taxonomic and cytological analyses. The experimental results of these investigations show:

(1) That the specific characters of *Rosa* are represented in sets of seven chromosomes called septets.

(2) That there are five fundamental species of *Rosa,* each species carrying in its gametes one distinct genetical septet of chromosomes, representing at least fifty specific characters.

(3) That the regular polyploid species of *Rosa* are made up of the various paired combinations of the five differential genetical septets making twenty-six species possible. Eighteen of these have been found and have been tested taxonomically, cytologically and genetically, leaving eight to be discovered, if they exist, one of which has already been made genetically.

(4) That the irregular polyploid species of *Rosa,* peculiar to Europe and Western Asia, are made up of various paired and unpaired combinations of the five differential genetical septets, making 180 species possible, many of which apparently do not exist.

Thus in *Rosa* 211 species are possible, each differing from another in the presence or absence of genetical septets of chromosomes and characters. Each species is therefore a discontinuous taxonomic unit subject to experimental verification by three distinct methods, taxonomic, cytological and genetical. Genetically each of these species is homozygous in its specific characters and either homozygous or heterozygous in its sub-specific, varietal and minor characters, while each species is taxonomically equivalent to a Linnean species.

In accordance with this conception, a species is a real entity, corresponding to the intuitions of the Old Systematists, though they were unable to demonstrate it experimentally.

The utility of such a conception of species in

classification and in the problems of distribution, speciation and phylogeny is evident, for it is clear that the chromosome complex is the vital mechanism of evolution, and there are welcome signs at this meeting that the physiologists and biochemists are coming to our aid in solving the pressing problem of the modes of action of the chromosomes in development.

C. C. HURST

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INTERNATIONAL CRITICAL TABLES

ONE of the major projects of the National Research Council has been the preparation and publication of International Critical Tables of Numerical Data in Physics, Chemistry and Technology, undertaken at the request of the International Union of Pure and Applied Chemistry and the International Research Council. The work of critical compilation began in 1922, and the first of the projected five large volumes was published last year. The responsibility for the editorial work has rested on Dr. E. W. Washburn, editor-in-chief; Dr. Clarence J. West, associate editor for chemistry; Dr. N. Ernest Dorsey, associate editor for physics; and Dr. F. R. Bichowsky and Dr. Alfons Klemenc, assistant editors. These responsible editors were assisted by an advisory editorial board composed of seven eminent chemists and physicists, and by ten corresponding editors and about 300 cooperating experts. The data used are derived from material in eighteen languages.

Nearly $200,000 has been expended on the compilation. This money has come as gifts from 244 firms and individuals and two major foundations (Carnegie Corporation and International Education Board). The gifts from these foundations, amounting to $70,000, were made for the special purpose of enabling the published tables to be sold at a price not prohibitive to individual buyers. Publication was undertaken by the McGraw-Hill Book Company, Inc., the well-known publishers of scientific books, under a special arrangement regarding selling price.

The regular price for a set of five volumes was fixed at $60, but a prepublication price of $35 a set was made to all subscribers ordering sets before the actual publication of Volume I.

The more optimistic among us estimated that we should have prepublication subscribers to the number of 1,000 to 1,500. The actual result is that 6,638 sets have been ordered at the pre-publication price of $35, and several hundred sets at the post-publication price of $60 a set. The distribution of these orders presents some interesting features.

Of the total of 6,638 sets ordered in advance of publication, 4,694 sets were ordered by individuals, 531 by libraries, 450 by educational institutions and 973 by industrial concerns.

As regards the geographical distribution of the orders a gratifying wideness in this distribution is apparent on going over the lists. The United States has ordered 4,867 sets, and foreign countries 1,771 sets. Fifty-three countries and colonies are represented in the foreign list with Great Britain and Ireland leading with 379 sets ordered, Germany next with 224 and Japan third with 146. France has ordered but 58 sets which are not as many as those ordered from Holland (91), Sweden (72) and Italy (67). Little Belgium has ordered 50 sets. Darkest Russia has ordered 27 sets, and benighted China 43 sets.

The total list of foreign countries, together with the figures of sets ordered follows: Africa, 20; Argentina, 19; Australia, 20; Austria, 37; Belgium, 50; Brazil, 5; Canada, 151; Ceylon, 1; Chile, 9; China, 43; Colombia, 2; Cuba, 10; Czechoslovakia, 37; Denmark, 31; Dutch East Indies, 17; Egypt, 1; Estonia, 4; Finland, 11; France, 58; Germany, 224; Guatemala, 1; Great Britain and Ireland, 379; Haiti, 1; Hawaii, 9; Holland, 91; Hungary, 9; Iceland, 1; India, 29; Italy, 67; Japan, 146; Jugoslavia, 4; Latvia, 3; Luxembourg, 1; Mexico, 17; New Zealand, 2; Norway, 38; Palestine, 2; Peru, 7; Philippines, 10; Poland, 12; Porto Rico, 7; Portugal, 1; Rumania, 8; Samoa, 1; Siam, 2; Soviet Russia, 27; Spain, 18; Straits Settlements, 3; Sweden, 72; Switzerland, 49; Syria, 2; Tasmania, 1; Trinidad, 1.

VERNON KELLOGG

NATIONAL RESEARCH COUNCIL,
WASHINGTON, D. C.

SCIENTIFIC EVENTS

EXCURSION OF THE INTERNATIONAL SOIL SCIENCE CONGRESS

THE national committee, which is planning for the work of the International Soil Science Congress, which is to meet in Washington on June 13, is arranging for an excursion through the United States to follow immediately after the close of the meeting on June 22.

The itinerary is now being worked out. It is planned to have the excursion go south from Washington to central North Carolina, thence across the mountains into Tennessee, southeast to Georgia, thence to Alabama and through Tennessee to southeastern Missouri, across that state to Kansas, thence either through Colorado, Utah and Nevada to California, or through Arizona and New Mexico to California, then north through Oregon and Washington to British Columbia,

east through Alberta and Saskatchewan to Manitoba, thence south through Minnesota, Wisconsin, Illinois, Indiana, Ohio, Pennsylvania and back to Washington. The party will travel by special train.

Stops will be made at all the experiment stations and agricultural colleges that can be reached on this trip and also a large number of additional stops are being planned to examine and study the soils in the various sections of the country. General agricultural conditions, type of crops, methods of tillage and similar features will also be taken up.

The tentative schedule for California calls for a stop in the Mojave Desert on the way in, then a day at Riverside, a day at Fresno and a day at Berkeley. The plans for these stops are not yet worked out, but provisionally, at Riverside a half day will be spent driving over that general portion of the state, visiting six selected excavations where the soil conditions can be studied and also visiting and studying citrus groves and irrigation and fertilization experiments. The afternoon will be spent at the Citrus Experiment Station studying the work that is there being carried on. At Fresno it is planned to spend a half day driving about the general region, visiting three or more representative excavations where the soil and subsoil conditions can be observed. Considerable time will be spent on the drainage and alkali reclamation tract at Kearney Park and in addition a visit will be made to the Association Packing Plant at Fresno. At Berkeley the entire time will be spent in the laboratories and greenhouses of the agricultural department.

THE SCIENTIFIC DIVISION COMMITTEE OF THE UNITED STATES FISHERIES ASSOCIATION

ON November 15, 1926, President Dana F. Ward appointed Lewis Radcliffe as chairman of the scientific division committee, a new division of the U. S. Fisheries Association, with instructions to select the committee and organize the group. Mr. Ward suggested that the "scientific division" would serve as an advisory committee in helping to establish the association's policy with respect to scientific investigations, to keep its members advised of advances in science and to aid in the building up of research organizations through federal, state and private agencies.

The following tentative program of operation has been evolved:

1. The branches of science selected for inclusion in the division's organization are—bacteriology, dietetics, economics, statistics and technology.

(a) Bacteriology plays a very important part in questions pertaining to the spoilage of food. Examples—reddening of cod; decomposition of canned foods; taking and marketing of oysters.

(b) Biological investigations must furnish the fundamental facts as a basis for sane legislation and to insure the highest development of our fishery resources without depletion or exhaustion.

(c) Dietetics—the fishing industry should capitalize on the revolutions of science as to man's food requirements. Aquatic products are unusually rich in elements shown to be necessary to man's well being.

(d) Economics—the accumulation of fundamental data on marketing of fish at home and abroad is basically essential to the growth, stabilization and permanence of our fisheries industries.

(e) Statistics—complete, continuous and comparable statistics of the catch are an essential to the proper husbanding of this resource; trade statistics in the fisheries industries as in others are necessary to level out the peaks and valleys of production and to serve as a stabilizing factor.

(f) Technology—through technological investigations and their application America has forged to the front in developing improvements in the methods of catching, handling and merchandising fishery products. Continued investigations on a larger scale are essential to maintenance of that position.

2. Division activities.

(a) To aid the association in developing a policy on scientific matters along broad fundamental lines.

(b) To coordinate the effort of federal, state, municipal and private scientific fisheries research agencies; promote harmony; and when requested, to advise such agencies as to lines of research which promise to be of greatest benefit to the fullest development of our fisheries for the common good of our people.

(c) To keep those engaged in American fisheries informed as to the advances made in the several sciences affecting fisheries. This would include reviews of scientific articles not easily accessible and their interpretation.

The scientific division committee consists of thirty-four members, divided into six sections. Dr. P. B. Parsons, New York Conservation Commission, Albany, is chairman of the bacteriology section; Elmer Higgins, U. S. Bureau of Fisheries, of the biological section; Dr. D. K. Tressler, Mellon Institute, of the dietetics section; L. T. Hopkinson, U. S. Tariff Commission, Washington, of the economics section; J. H. Mathews, New York City, of the statistical section, and H. F. Taylor, Atlantic Coast Fisheries Co., New York City, of the technological section.

FELLOWS OF THE ROYAL SOCIETY OF EDINBURGH

AMONG the candidates recommended by the council for election as fellows of the Royal Society of Edin-

burgh are the following: D. A. Allan, lecturer in geology, Armstrong College, Newcastle-upon-Tyne; S. E. Bastow, managing director, Bruce Peebles and Co., Limited; D. L. Bryce, student of microzoology, Quekett Microscopical Club, Surrey; H. G. Cannon, professor of zoology, Sheffield University; T. M. Finlay, lecturer in paleontology, Edinburgh University; A. W. Greenwood, assistant in the animal breeding research department, Edinburgh University; J. M. Gulland, demonstrator in organic chemistry, Oxford University; H. S. Holden, senior lecturer in botany, University College, Nottingham; O. D. Hunt, assistant naturalist, Plymouth Marine Station, temporary lecturer in zoology, Glasgow University; J. Hyslop, lecturer in mathematics, Glasgow University; E. T. Jones, professor of natural philosophy, Glasgow University; W. P. Kennedy, Carnegie research fellow in physiology, Edinburgh University; J. M. M. Kerr, professor of midwifery, Glasgow University; C. G. Lambie, lecturer in clinical medicine and assistant in therapeutics, Edinburgh University; D. McIntyre, assistant physician, Glasgow Royal Maternity and Women's Hospital and Glasgow Samaritan Hospital; M. R. Madwar, assistant Helwan Observatory, Egypt; F. N. K. Menzies, medical officer of health and school medical officer, London; T. P. Noble, professor of surgery, University, Bangkok, Siam; W. J. Owen, Member Royal Society Victoria, histologist, National Museum of Australian Zoology; C. Patterson, Marine Engineers, lecturer in mechanical engineering, design and theory of machines, Edinburgh University; H. H. Read, senior geologist, H. M. Geological Survey; J. E. Richey, district geologist, H. M. Geological Survey, Scotland; I. Sandeman, science master, George Heriot's School; R. Schlapp, lecturer in applied mathematics, Edinburgh University; F. W. Sharpley, professor of electrical and mechanical engineering, Indian School of Mines, Dhanbad, India; E. Shearer, professor of agriculture and rural economy, Edinburgh University; C. W. Wardlaw, lecturer in botany, Glasgow University; W. T. H. Williamson, assistant lecturer in chemistry, Edinburgh and East of Scotland College of Agriculture.

NATIONAL RESEARCH FELLOWSHIPS IN THE BIOLOGICAL SCIENCES

THE board of national research fellowships in the biological sciences announces the following appointments and reappointments for the year 1927–28, made at its meeting on February 4 and 5:

REAPPOINTMENTS

Kenneth S. Cole, biophysics
Sherburne F. Cook, botany
Carroll Lane Fenton, paleontology
Adriance S. Foster, botany
Samuel M. Gordon, biochemistry
Harry D. Kruse, biochemistry
Eduardo Quisumbing, botany
R. C. Travis, psychology
Conway Zirkle, botany

NEW APPOINTMENTS

Dean Turner Burk, botany
Robert Emerson, botany
Hudson Hoagland, psychology
Theodore F. Karwoski, psychology
Otto Klineberg, psychology
Raymond C. Parker, zoology
Gregory G. Pincus, zoology
George Salt, zoology
Charles F. Swingle, botany
Raymond H. Wallace, botany

The second, and in all probability the final, meeting of the board for the year for the consideration of 1927–28 appointments is planned for the latter part of May. Applications for this meeting should be filed by April 15. Information and application forms may be obtained from the Secretary, Board of National Research Fellowships in the Biological Sciences, National Research Council, Washington, D. C.

FRANK R. LILLIE, *Chairman*
Board of National Research Fellowships in the Biological Sciences

SCIENTIFIC NOTES AND NEWS

THE two hundredth anniversary of the death of Isaac Newton on March 20 will be celebrated at Grantham in Lincolnshire, where Newton attended the grammar school and at Woolsthrope Manor House, his birthplace, six miles away. There will be meetings at which Sir J. J. Thomson, Sir F. Dyson, Dr. Horace Lamb, Professor G. H. Hardy and Dr. J. H. Jeans will speak.

ON February 24 a dinner was given in honor of Dr. A. P. Coleman, F.R.S., professor emeritus of geology in the University of Toronto. It was arranged by some of his colleagues, former students and other friends, and was the occasion of the presentation to the University of Toronto of a portrait of Professor Coleman and also of a fund for the maintenance of a gold medal to be known as the Coleman Medal. This medal is to be awarded annually to the student who has obtained, at the time of graduation, the highest standing in his class in geology and mineralogy.

DR. LORRAIN S. HULBURT, collegiate professor of mathematics in the Johns Hopkins University, has retired from active service. Dr. Hulburt has been a member of the faculty of the university for thirty-

four years. He will continue to live in Baltimore. Dr. A. Cohen, for many years associate professor of mathematics in the university, succeeds Dr. Hulburt as collegiate professor of mathematics.

DR. WILLARD ROUSE JILLSON, state geologist and director of the Kentucky Geological Survey, has been elected a fellow in the Royal Geographical Society, London.

ERNEST THOMPSON SETON, naturalist of Greenwich, Conn., has been awarded the John Burroughs Memorial Association medal, for his recent work on "The Lives of the Game Animals." The medal will be presented at the annual meeting of the association on April 2 at the American Museum of Natural History. Last year the medal was awarded to William Beebe for his literary work in connection with the *Arcturus* expedition.

DR. LUCIEN HOWE, emeritus professor of ophthalmology at the University of Buffalo, has been awarded the Leslie Dana medal, given each year through the Missouri Association for the Blind to the individual who has accomplished the most for the blind in the United States and Canada.

DR. EDWARD W. ARCHIBALD, professor of surgery at McGill University, Montreal, has been elected an honorary fellow of the New York Academy of Medicine.

DR. GEORGE BACHMANN, professor of physiology at Emory University, was inducted as a fellow of the American College of Physicians at the meeting held recently in Cleveland.

DR. ETIENNE BURNET, assistant director of the Pasteur Institute at Tunis, and Dr. Chaumier, of Tours, known for his vaccine lymph, have been elected national correspondents of the French Academy of Medicine.

PROFESSOR U. M. KOLOSOV, of the Sverdlovsk University (Urals), has been elected a member of the French Entomological Society for his work on the insects of Eastern Russia.

AT the annual general meeting of the British Physical Society, held on February 11, Professor O. W. Richardson was elected president.

AT the anniversary meeting of the Geological Society of London, held on February 18, the following officers were elected: *President,* Dr. F. A. Bather; *vice-presidents,* Dr. J. W. Evans, Professor E. J. Garwood, Dr. E. Greenly, Mr. H. W. Monckton; *secretaries,* Mr. W. Campbell Smith and Dr. J. A. Douglas.

PROFESSOR ALEXANDER EVGENIEVICH FERSMAN, the well-known Russian mineralogist, was elected vice-president of the Academy of Sciences of Leningrad, Russia, at a special meeting which was attended by many members of the academy from Moscow, Kieff, Kharkoff and other cities in Russia, who came to Leningrad especially for this occasion. Professor Fersman is well known as the author jointly with Dr. Victor Goldsmidt of a volume on the crystal forms of diamonds. He has written a number of scientific works, among them a unique volume on "The Russian Natural Color Stones" and two volumes on "The Known Precious Stones of Soviet Russia."

PERCY VIOSCA, state biologist of Louisiana and president of the Southern Biological Supply Company, Inc., has been appointed director of the fisheries division, Department of Conservation, of Louisiana.

DR. GEORGE GRANT MACCURDY, of Yale University, director of the American School of Prehistoric Research, has been designated to represent the Paris Society at the commemoration of the two hundredth anniversary of the founding of the American Philosophical Society, to be held in Philadelphia, April 27 to 30.

DR. WILLIAM BOWIE, of the U. S. Coast and Geodetic Survey, was the official representative of the American Association for the Advancement of Science at the annual meeting of the Joseph A. Holmes Safety Association held in Washington on March 5.

DR. J. G. FITZGERALD, professor of hygiene, will be given leave of absence in order to attend the International Rabies Conference called by the health committee of the League of Nations to meet in Pasteur's old home in Paris next April.

DR. JULIAN L. COOLIDGE, professor of mathematics at Harvard University, has been appointed Harvard exchange professor to France, in place of Professor A. B. Hart, for the second half of the current academic year.

DR. WILLIAM B. PORTER sailed on March 3 for Europe, where he will spend several months visiting medical centers preliminary to assuming the full-time professorship of medicine at the Medical College of Virginia at Richmond.

BEGINNING with the first of the new year and continuing on up to September 1, a leave of absence has been granted to Dr. W. T. Pearce, dean of the School of Chemistry at the North Dakota Agricultural College.

DR. MARY LOUISE FOSTER has received leave of absence from Smith College to go to Madrid to equip the new laboratory and organize the course in chemistry given to the women of the University of Madrid under the combined auspices of the Junta para am-

plición de los estudios científicos and the International Institute for Education of Girls in Spain.

DR. BERNHARD NEBEL, of the University of Halle, Germany, is spending six months at the New York State Agricultural Experiment Station under the auspices of the International Education Board. Dr. Nebel is making a study of the fruit breeding work at the station, and later will spend some time at the California Experiment Station at Davis in a study of citrus fruits.

DIRECTOR FRANCISCO LOPEZ DOMINGUEZ, of the Insular Experiment Station of Porto Rico, has been appointed delegate to the meeting of the International Society of Sugar Cane Technologists, Havana, Cuba, representing the Insular Department of Agriculture of Porto Rico and the Sugar Producers' Association. He sailed on March 3 and expects to return about May 1. Dr. Melville T. Cook, plant pathologist of the Insular Experiment Station, has been appointed acting director during the absence of the director.

DR. ALFRED EISENSTEIN, of Vienna, and Mr. H. B. Jespersen, of Copenhagen, are spending a few weeks with Arthur D. Little, Inc., of Cambridge, Mass., with whom they are associated as European correspondents and consultants.

DR. ROGER ADAMS, professor of chemistry at the University of Illinois, addressed the scientific staff of the Rockefeller Institute for Medical Research, New York, on March 11 on "Chaulmoogra Oil."

DR. BURTON E. LIVINGSTON, professor of plant physiology at the Johns Hopkins University, delivered the annual address before the Tau chapter of Phi Sigma at Duke University, February 28, on "The Relation of Water to Plants."

ON February 26, Barnum Brown, curator of fossil reptiles, American Museum of Natural History, New York, delivered an address to the Royal Canadian Institute, on the subject "Highways and Byways in Burma."

DR. ROBERT H. GAULT, director of the vibro-tactile research laboratory, Smith College, Northampton, Mass., addressed the Franklin Institute on March 24 on "The Interpretation of Speech by Tactual and Visual Impression."

ON February 23, Professor Paul S. Welch, of the department of zoology, University of Michigan, gave a public lecture before the Michigan chapter of Sigma Xi on "Biological Research Conditions in Europe."

DR. WILLIAM BOWIE, chief of the division of geology, U. S. Coast and Geodetic Survey, gave three lectures on isostasy before the students and faculty of the department of geology of the University of Wisconsin on the afternoons of February 16, 17 and 18; and one general lecture on isostasy to the public, on the evening of February 18.

PRESIDENT EMERITUS E. A. BIRGE, of the University of Wisconsin, gave an address on March 1 before the university chapter of Sigma Xi entitled "Science."

PROFESSOR SAMUEL G. BARTON, of the department of astronomy at the University of Pennsylvania, gave a lecture on "The Earth's Motions and their Consequences" at the Brooklyn Institute of Arts and Sciences on March 11.

DR. HUGH S. CUMMING, surgeon-general United States Public Health Service, will be the commencement speaker at the Medical College of Virginia at Richmond on May 31. Dr. Cumming is an alumnus in medicine both of the University of Virginia and the Medical College of Virginia.

DR. FRANK H. LOUD, emeritus professor of mathematics and astronomy in Colorado College, has died at the age of seventy-five years.

DR. JAMES ROBERT ERSKINE-MURRAY, F.R.S., well-known British authority on wireless telegraphy, died on February 12, aged fifty-eight years.

CARLOS MARIA SCHUEL, student of natural history and curator of the local museum, died at Jujuy, Argentina, on February 7, at the age of sixty-nine years.

WORD has been received from Leningrad of the death of Dr. Jacobson, the well-known coleopterist.

DR. R. A. MILLIKAN, director of the Norman Bridge Laboratory of Physics of the California Institute of Technology, will deliver a course of twelve lectures before the graduate school of the Ohio State University on "Twentieth Century Discoveries in Physics." The dates and subjects of the individual lectures are as follows: April 11 at 8 P. M., "The Birth of Two Ideas"; April 12 at 4 P. M., "The Discovery of the Electron"; April 12 at 8 P. M., "Seeing the Invisible"; April 13 at 8 P. M., "Gulliver's Travels in Science"; April 14 at 4 P. M., "Light Darts"; April 14 at 8 P. M., "Stripped Atoms"; April 15 at 4 P. M., "The Birth of a Light Ray"; April 15, at 8 P. M., "Cosmic Rays"; April 16 at 11 A. M., "Relativity inside an Atom"; April 18 at 4 P. M., "Pulling Electrons out of Metals"; April 18 at 8 P. M., "Isotopes and their Significance"; April 19 at 4 P. M., "Spectroscopic Prediction."

THE teaching staff for the new school for the study of outdoor natural history to be conducted this summer in the Allegany State Park, about 75 miles south of Buffalo, has been announced by Chauncey J. Hamlin, president of the Buffalo Society of Natural Sci-

ences, and Dr. Charles C. Adams, director of the New York State Museum. The director of the new school is Dr. Robert E. Coker, professor of zoology in the University of North Carolina. Dr. Coker will also give a field course in zoology, giving special attention to aquatic animals. The dean of women is Mrs. R. E. Coker, who will look after the welfare of the women. The instruction in field geology and physical geography is given by Professor Allen C. Tester, of the University of Iowa. The field botanical course will be given by Norman Taylor, botanist, of the Brooklyn Botanic Garden, and the field course on birds, by Aretas A. Saunders, of Fairfield, Conn. The nature study instruction will be given by W. P. Alexander, of the Buffalo Society of Natural Sciences, and the instruction covering park problems and park management, by Professor Henry R. Francis, of the department of recreational forestry of the New York State College of Forestry at Syracuse.

THE thirteenth annual convention of the American Association of Cereal Chemists will be held at Hotel Fontenelle, Omaha, Nebr., from May 30 to June 3.

AT the invitation of the American Association of Economic Entomologists and the Entomological Society of America, the fourth International Congress of Entomology will be held at Ithaca, N. Y., probably in the third week of August, 1928. A preliminary program will be issued in the near future.

PROPOSED anti-evolution legislation received a setback in the Minnesota legislature on March 10 when the house committee on education, by a vote of 12 to 5, recommended indefinite postponement of a measure that would bar teaching of evolution theories in tax-supported schools.

THE anti-evolution bill, introduced in the North Carolina legislature that has just concluded its session, was voted down in committee by a large majority. Those in favor of the bill decided not to bring it to a vote in the house.

AT the request of the United States geographical board, Governor W. J. Fields, of Kentucky, formed on March 9 the Kentucky Geographic Council to cooperate with the national board in the work of preparing a geographic dictionary of the United States. Dr. Willard R. Jillson, director of the Kentucky Geological Survey and state geologist, was made chairman of the council. The other members are Otto A. Rothert, of Louisville, secretary of the Filson Club, and H. V. McChesney, of Frankfort, first vice-president of the Kentucky State Historical Society.

ANNOUNCEMENT has been made of the establishment of a new journal by the Chinese Physiological Society, entitled *The Chinese Journal of Physiology*, which is to be issued quarterly. The society is composed of the physiologists, biochemists and pharmacologists of China. Membership is open to all workers (Chinese and foreigners) in the physiological sciences in China.

FOUR German universities will celebrate the anniversary of their foundation this year—namely, Würzburg, founded 1402 (exact date unknown); Tübingen, October 9, 1447; Marburg, May 30, 1527, and Breslau, November 15, 1702.

THE Sir William Dunn school of pathology at Oxford University was opened on the afternoon of March 11, by Viscount Cave, lord chancellor of England and chancellor of the university.

THE American Forestry Association has announced an offer of $100,000 by George D. Pratt, president of the association, to be applied toward a $200,000 endowment to carry on the educational work of the association. The offer is contingent upon the raising of the remaining $100,000. $60,000 of this amount is already available in the reserve fund of the association. The remaining $40,000 will be raised by solicitation among the members of the association and for new members.

THE University of Michigan has received a gift of $45,000 a year from July 1, 1927, for five years, from anonymous sources, to be used toward "discovering and promoting scientific knowledge of the causes, prevention and cure of cancer and other growth processes." Under the terms of the gift President C. C. Little is designated director of the research contemplated. Dr. L. C. Strong, of the Bussey Institution, Harvard University, is to be one of the investigators.

MISCELLANEOUS gifts totalling $32,550, besides apparatus and records, have been announced by Columbia University. Physics appliances valued at $7,100 were donated by the Optometrical Society of the City of New York, the Optometrical Club of Brooklyn, the Epsilon Psi Epsilon Fraternity, the General Optical Company and the Hamilton Manufacturing Company, while the American Optical Company loaned an additional $1,750 worth. Donors of money included: Mrs. Frederic S. Lee, Blair S. Williams and an anonymous donor, for immediate needs under the direction of the president, $7,700; General T. Coleman du Pont, for special tuberculosis fund, $5,000; Mrs. Edward D. Faulkner, for salaries in the department of surgery, $2,500; Copper and Brass Research Association, for the copper and brass fund, $2,500; A. S. Rosenthal, for medical research in pathology, $2,500.

MRS. C. V. RILEY, widow of Dr. Riley, predecessor of Dr. L. O. Howard as chief entomologist of the U. S. Department of Agriculture, has donated to the library of the National Museum the scrapbooks of economic entomology which were kept by her husband in the period of his activity from 1865 to 1894. These volumes, about one hundred in number, contain many articles of great historical interest. In giving these scrapbooks to the museum, Mrs. Riley wished to have them housed in the same place as the Riley collection of insects.

UNIVERSITY AND EDUCATIONAL NOTES

THE University of Missouri will ask the state legislature for an appropriation of $6,348,962.39 for the biennium of 1927–28. This is $227,920.29 less than was requested two years ago. The Missouri School of Mines and Metallurgy is asking the state legislature for $1,227,250 for the next two years.

A GIFT of $25,000 to Howard University's medical school $250,000 endowment fund by Julius Rosenwald, of Chicago, has been announced.

PHILLIPS ANDOVER ACADEMY has been presented with $125,000 by A. I. du Pont, of Wilmington, Del., for use in completing the $300,000 science building.

ON March 5 the medical college of The Long Island College Hospital, Brooklyn, inaugurated its new course in "Medical Literature and Bibliography." In a number of schools the importance of bibliographical knowledge has been stressed by individual teachers, but this is said to be the first established course of this nature included in the curriculum of a medical school in this country. An attempt is being made to show the student the value of literature which constitutes an important part of the background of his work; and to teach him how to use a library. The faculty has secured as a lecturer Mr. Charles Frankenberger, librarian of the Medical Society of the County of Kings, whose wide knowledge of bibliography and of the relative values of medical literature can now be made available for the medical student as a part of his training.

A FACULTY of mechanical engineering and mining chemistry and technique is to be founded in the University of Münster, Westphalia, at a cost of 1,500,000 marks. A contribution of 1,000,000 marks has been promised by the provincial government, and 500,000 marks have been received from industrial bodies.

DR. ALFRED OWRE, dean of the school of dentistry at the University of Minnesota, has been named dean of the school of dental and oral surgery at Columbia University, succeeding Director Frank T. Van Woert, who is to be relieved of administrative duties at his own request.

AT Harvard University, Dr. Oliver D. Kellogg has been promoted to a full professorship of mathematics. Other promotions include those of Dr. E. A. Hooton, assistant professor of anthropology, and Dr. William Henry Westen, assistant professor of botany, to be associate professor.

PROFESSOR L. D. AMES, of the Texas Technological College, has been appointed professor of mathematics at the University of Southern California.

DR. H. B. ENGLISH, associate professor of psychology at Wesleyan University, has resigned to take a position at Antioch College.

DISCUSSION AND CORRESPONDENCE

THE COLOR OF HYDRATED SILICA AND ALUMINA

DURING a study of the hydration of silica, alumina and ferric oxide I noticed that alumina became more and more colored as its hydration increased. The anhydrous oxide Al_2O_3 is snow white by either reflected or transmitted light. The hydrated form $Al(OH)_3$ is a decided tan or even brown by transmitted light, but the complementary bluish white by reflected light. A small flake or chip of the hydroxide under a low power microscope shows the effect nicely since the light is easily shifted. Silica shows a precisely similar effect as the SiO_2 goes over to the orthosilicic acid $Si(OH)_4$.

In other words, these hydrated oxides show a pronounced *dichroism* while the oxides do not. This dichroism is a useful qualitative test for the degree of hydration. Previous workers have evidently attributed the brownish color to traces of iron, overlooking the bluish tint of the same particle by reflected light. Either precipitates or suspensions of either hydrate show the effect very well. I have not been able to locate definite *steps* in the hydration of either oxide by this means, to do that would require rather precise spectrophotometric data. Most complex oxides apparently do *not* show similar dichroism on hydration, but only a hasty survey has yet been made.

An interesting application to meteorology is evident in relation to sky colors. Both silica and alumina are strongly hygroscopic, adsorbing water films (at even low humidities) many molecules deep. Due to the intense internal pressures in these films on minute particles, hydration is relatively rapid. Hence we should expect that dust particles (largely

silica and alumina) in the atmosphere would in a few hours or days become partly hydrated appearing brownish or yellowish toward the sun, bluish at a wide angle from the sun, just as commonly observed.

P. G. NUTTING

U. S. GEOLOGICAL SURVEY

A CRITERION FOR DISTINGUISHING IDENTICAL TWINS FROM FRATERNAL TWINS

APART from the examination of the placenta and foetal membranes at birth, there is no safe criterion of distinguishing the identical twins from the fraternal twins. In the course of study on my collection of finger prints and hand and sole prints of some twins I have come to realize that, generally speaking, the same hands or feet of the identical twins resemble each other more closely in their patterns than the two hands or feet of the same individual. To represent in symbols, let r and l stand respectively for the right and left hand or foot of the one twin A, and r′ and l′ respectively for the right and left hand or foot of the other twin A′ which is identical with A, then:

$$r-r' \text{ (or } l-l') < r-l \text{ (or } r'-l').$$

This statement holds good in principle also for the several identical twins studied by Wilder (04, 19), Pol (14), Bonnevie (23, 25), Kuragami (26) and Montgomery (26); while such a condition can never be found in twins of different sexes nor in twins of the same sex bearing evidence for their being fraternal twins. Thus, we seem to be justified by saying: "Such twins are identical twins in which the same hands or feet of different individuals are more alike than the different hands or feet of the same individual."

But this statement must not be taken as involving the notion also that, if the former resemblance is less than the latter resemblance, the given twins are fraternal, since there are some twins which are apparently identical and yet do not show the condition mentioned above. Anyway, this will probably serve as a criterion for identifying some identical twins.

Some writers on twins and twinning, such as Bateson (13) and Newman (17), seem to hold the view that the identical twins are comparable with the right and left halves of the body of one person. The view could not be quite correct, should it imply that the resemblance between the identical twins is in principle equal to the resemblance between the right and left halves of one person. As a matter of fact, speaking generally, the resemblance between the identical twins is more than that between the halves of one person. Aside from the fact that the viscera show a marked asymmetry and the situs inversus viscerum is exceptional, even among identical twins, there are several cases known where such twins have the same defect or abnormality on the same side of the body. Moreover, as mentioned above, the hands or feet of the same side of different twins show closer resemblance than the two hands or feet of the same individual.

TAKU KOMAI

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THE "TEARING METHOD"

DR. K. HOROVITZ, who is working at present in my laboratory, has just pointed out to me a very important paper which I had unfortunately overlooked, and which gives strong support to the letter I published in SCIENCE (Feb. 11, 1927, p. 160). This article, by no less an authority than P. Lenard, is entitled, "Über Oberflächenspannungmessungen besonders nach der Abreiszmethode . . ." (*Ann. der Physik,* 1924, lxxiv, 381–404), and contains a highly interesting study of the "tearing method" (a horizontal rod being used instead of a ring). The conclusions of the paper are that: "Es ist dadurch . . . der *einfachste und zugleich zuverlässigste* Weg zu *genauester, absoluter* Oberflächenspannungmessungen leicht gangbar gemacht." ("The *most accurate absolute* measurements of surface tension . . . ")

In his determination, Lenard uses the method which I described in 1919, namely, a torsion balance. I may furthermore recall that the plate illustrating my first description of the tensiometer showed the instrument with a rod and not with a ring; the ring was adopted later, mainly on account of the smaller amount of liquid required for the measurements, and of the fact that no correction was required for the capillary action on the two perpendicular rods of the frame.

LECOMTE DU NOUY

ROCKEFELLER INSTITUTE
FOR MEDICAL RESEARCH

STUDY OF BARTLETT PEAR BLACK-END UNDERTAKEN IN CALIFORNIA

AN extensive study of the black-end of the Bartlett pear has been undertaken by the division of pomology, University of California. This disease, which is physiological in nature, has been taking heavy losses during recent years in practically all pear sections of the state. In view of the fact that the losses seemed to be increasing from year to year it was thought advisable that a systematic study be made of the disease and also possible methods of control worked out.

The early stages of the black-end are evident while

the fruit is quite small. The epidermis of the fruit around the calyx end becomes shiny and tight in appearance. Coincident with these manifestations, the calyx lobes are forced out so that they appear to be set on top of a "peak." As the fruit develops the calyx end either turns black, involving the epidermis as well as the flesh, or else it becomes very hard and gritty. In either case the fruit finds no commercial value.

A canvass of the state pear sections the past summer showed that in practically every case where the abnormal fruit was developed the Bartlett was growing on the Japanese root, *Pyrus serotina,* and in only a few scattered cases on the French root, *Pyrus communis.* The latter were found where the trees were growing in soils that were very heavy and wet for a considerable length of time. As far as the one season's work is concerned, it appears as though there is a relation between the development of the abnormal fruit and the rootstock being used.

In addition to the rootstock studies mentioned above histological studies of the fruit have been undertaken in order to determine whether any structural changes occur in the abnormal as compared with the normal fruit. Also, experimental work is under way along control lines.

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SCIENTIFIC BOOKS

Man and Weather. By ALEXANDER MCADIE. Cambridge, The Harvard University Press, 1926. 99 p., 19 illus.

THERE is so much good in the best of it, but so much bad in the worst of it, that this latest little book by McAdie left the reviewer depressed. The trouble seems to be this: Here is an author whose leaning toward the popular presentation of science is being almost constantly demonstrated, who nevertheless seems in this book not thoroughly careful as to how he goes about it. In fact, one is in some quandary over deciding what effect McAdie really wanted to produce in the minds of his hearers (the book is "essentially a series of lectures delivered in the Lowell Institute Course in December, 1924"). For on page 21, in the chapter on "Weather in Peace," he reminds them of the benefits to be derived if we could but forecast the character of the weather far ahead, and then, as on pages 27 and 28, says: " . . . It does appear that it is now possible to forecast periods of excessive rainfall and on the other hand droughts."

" . . . it is not difficult to forecast scanty rainfall and the absence of floods. As mentioned above, the month of March, 1915, ushered in a period of scanty rains which continued until midsummer . . . Or take another illustration . . . the drought of 1921 in northwestern Europe, which resulted in less than half a normal rainfall." The shortening of sentences in these quotations in no wise increases the effect of the author's words as an implication that conditions in March, 1915, or those preceding the drought of 1921 *foreshadowed* the coming droughts.

There is no other interpretation of the words than that the meteorologist's dream of being able to make satisfactory long-range forecasts has come true. And there is nothing of which the meteorologist is more keenly aware than that the dream has *not* come true. To be sure, in India, the comparative simplicity of the factors which affect seasonal rainfall in that country has made possible a fair degree of success in seasonal forecasting. For parts of California also, there seems to be evidence that we are on the eve of attaining similar success. But that is no justification for leading the non-meteorological public to infer far more than the most sanguine meteorologist dares to, on the basis of his present knowledge.

In the chapter on "Drought, Floods and Forecasts" the lecturer (referring to the California rainy season) again similarly confuses hindsight with foresight, thus, on page 97, "When the continental hyperbar is displaced to the northwest, the general drift of surface air being from northeast, the winter *will be* (reviewer's italics) dry."

Quite so, if you change that careless *will be* to *is.* So also with a statement of conditions favoring on the one hand heavy, and on the other hand deficient, precipitation. The thing reads as if we could predict, on the basis of current pressure conditions in the autumn, what the pressure conditions and therefore the rainfall are to be, in the winter. No one is in a position to forecast, for California or any other part of the country, the distribution of atmospheric pressure even a week ahead, to say nothing of a month or a season. Yet here is long-range forecasting advertised by the Abbott Lawrence Rotch professor of meteorology in Harvard University and the director of Blue Hill Observatory, as a *fait accompli.* One may reverently hope that the shade of Rotch was not present at those lectures.

We note the seemingly inevitable illustration from the "Tower of the Winds"; some good cloud pictures scattered in no discoverable relation to the text; a picture of a "Cumulo-stratus," the term being obsolete in cloud classification; the repetition, in a chapter on "The Strategy of Weather in War," of material from an earlier, delightful book by the same author;

and the persisting effort to urge certain changes of terminology upon an unwilling science. With respect to this last item, the reviewer hopes, however, that some day meteorology will no longer remain unwilling to adopt McAdie's "hyperbar" and "infrabar."

Let it be clearly said that the general reader will discover in this book much to interest and inform him, a very great deal that is most attractively written, occasionally a little masterpiece. He will, it must be pointed out, feel that the going is sometimes a little uneven, for there are bumps of technical matter by no means adequately smoothed out for the layman. Some of these are probably beyond legitimate smoothing for a book of this kind; they would better be omitted altogether. But the recommendation is emphatically to read "Man and Weather," nevertheless.

BURTON M. VARNEY
WASHINGTON, D. C.

Nomenclator animalium generum et subgenerum. Published by the Prussian Academy of Sciences, Berlin.

THE plan of this work traces back more than twenty years. Franz Eilhard Schulze, the editor of "Das Tierreich," also formed the original plan for this comprehensive index of the correct names of the genera and subgenera of the animal kingdom. After his death, W. Kükenthal became the editor and at the present time it is continued by K. Heider as editor and Th. Kuhlgatz as responsible manager. The work will not only enumerate all the names of the genera and subgenera including the paleontological names, but as far as possible will give for them the exact reference of their first employment. Since it was the original plan not to go beyond the literature of 1909, these detailed statements are given only for those names which came into use previous to this date. For all the names that originated from 1910 through 1922 the references of the *Zoological Record* will be given. Most of the subdivisions have been worked out by specialists, the bureau of the "Nomenclator Commission" of the Prussian Academy of Sciences directly taking care of the few remaining fields for which specialists could not be found.

Doubtless this work, of which four issues have left the press, will prove to be of greatest usefulness to workers in all fields of zoology, and one can but admire the great amount of prosaic work necessary to accomplish it. The entire work will comprise five volumes, each of which will be published in five issues. Subscriptions are to be sent to the Preussische Akademie der Wissenschaften, Unter den Linden 38, Berlin NW 7. The subscription price is 15 marks for every issue (160 pages, approximately) and will change to 20 marks after March 31 of this year.

WALTER LANDAUER

SPECIAL ARTICLES

THE INFLUENCE OF SELECTIVE AND GENERAL IRRADIATION BY A QUARTZ MERCURY ARC LAMP UPON THE GERMINATION AND GROWTH OF SEEDS

DURING the last few months we have been conducting experiments (1) to determine the effects produced upon the germination and growth of seeds by selective irradiation as obtained by the use of filters which screened out, by progressive steps, the various portions of the ultraviolet radiation from a quartz mercury-arc lamp and (2) to determine the daily growth of various seedlings when irradiated from one, two, five and ten minutes, respectively, under the same lamp, and when grown in darkness or under subdued daylight as transmitted by ordinary window glass. The experimental conditions were maintained as uniformly as possible with reference to temperature, moisture, character of containing vessels and methods of handling seedlings. An air-cooled quartz mercury lamp of the Victor X-ray Corporation type was operated at 70 volts and was used at a distance of 50 cm. The lamp was standardized and found to produce a grade 1 reaction (transient erythema) of the normally unexposed skin of the upper arm in three minutes at a distance of 50 cm and a grade 2 reaction (permanent erythema) in six minutes.

SELECTIVE IRRADIATION

Table I contains a sample set of data obtained on the germination and growth of cucumber seedlings; the character of the irradiation, the periods of exposure to the quartz mercury lamp, and the subsequent disposition of the seedlings (that is, whether kept in the subdued daylight of the room or in darkness) are also given.

The conclusions which we believe we are justified in drawing are:

(1) Selective irradiation of the seed modifies the time of its germination and rate of its subsequent growth.

(2) The lesser wavelengths, in general, appear to stimulate while the greater wavelengths inhibit germination.

(3) Wavelengths ranging from about 320 mμ to 390mμ seem particularly effective in inducing growth.

(4) Wavelengths of 270 mμ to 320 mμ appear to be inhibitory in their action, and delay the time and lessen the rate of growth, probably because of changes

which, carried to their extreme, eventuate in coagulation of the seed albumin.

(5) Some of the energy emitted by the lamp and absorbed by the seed may be rendered ineffective by subsequent exposure of the seed to the visible and near infra-red regions of interior daylight.

(6) Certain wavelengths of radiant energy are more potent in germination than temperature. With a constant temperature, germination and growth in the dark greatly exceed those in the daylight as transmitted by ordinary window glass.

(7) A certain amount of energy, apparently produced under the action of the lesser wavelengths of sunlight, is normally stored up within seeds. Under proper conditions of light and moisture this energy induces germination.

(8) Lesser wavelengths of light act as stimulative agents which modify the control of endogenous processes and accelerate germination, while subsequent growth and development of the plant is doubtless a function of the visible or infra-red wavelengths.

General Irradiation

In these experiments, various seeds (lettuce, radish, and turnip) were placed in similar containers and kept under identical and as nearly as possible uniform conditions of temperature and moisture. Table II contains a specimen set of data upon the germination and daily growth of turnip seedlings when directly irradiated by the mercury lamp for daily periods of one, two, five and ten minutes, respectively. Half of the seedlings were kept in darkness, while the others were placed under diffuse daylight.

From these series of experiments we conclude:

(1) In seeds which normally germinate and grow in darkness and underground, the most rapid germination and maximal growth were attained by the normal non-irradiated seeds and roots kept constantly in darkness.

Table I

Length (mm.) of seedlings grown under varying experimental conditions

	I		II		III		IV		V	
Elapsed time in hours	Ultra glass (a) dark	(b) light	Vitaglass (a) dark	(b) light	Ordinary glass (a) dark	(b) light	Direct radiation (a) dark	(b) light	Control (a) dark	(b) light
40	4	4	3	1	2	0	3	0	0	0
64	14	14	10	6	9	0	7	1	9	0
88	36	24	27	14	23	1	19	5	28	2
112	54	30	42	20	35	2	30	8	52	6
136	65	37	47	25	44	3	31	5	63	8
184	70	40	55	25	60	3	31	5	82	6

Pots I(a) and I(b) were exposed to the radiation of the mercury quartz lamp for 20 minutes each day. Pots II(a) to IV(b) inclusive were irradiated by the same source for 5 minutes daily.

Ultra glass (Corning 586 A W) transmits from 390 to 320 mμ with a maximum at 370 mμ. Vitaglass (Lamplough) transmits to 270 mμ; ordinary glass to 320 mμ.

Table II

Daily growth of turnip seedlings (mms.) under specified experimental conditions

	I		II		III		IV		V	
Elapsed time in hours	Irradiated 1 minute daily dark (a)	light (b)	Irradiated 2 minutes daily dark (a)	light (b)	Irradiated 5 minutes daily dark (a)	light (b)	Irradiated 10 minutes daily dark (a)	light (b)	Non-irradiated controls dark (a)	light (b)
28	1	0.5	2	1	2	2	2	2	3	0
52	5	2.5	3	4	6	5	6	5	7	0.5
76	18	6	14	12	11	15	7	12	25	1
100	24	11	20	19	12	15	7.5	12	33	1
124	35	20	27	25	13.5	14	9	12	42	4
148	42	30	35	35	15	13	10	13	50	4
172	46	35	42	40	15	13	10	13	60	12
196	50	40	47	52	15	13	10	13	70	12

All seeds and seedlings irradiated by a mercury quartz lamp, operated at 70 volts, at a distance of 50 cm. Seedlings grown in a dark cabinet are indicated by (a): those grown under subdued or interior daylight as transmitted by ordinary window glass are designated (b).

(2) The amount of growth of the seedlings kept in darkness decreases with the amount of irradiation. The total growth (L) of the root is inversely proportional to the logarithm of the total time of irradiation (n·t). That is,

$$L = k\frac{1}{\log\ (n \cdot t)}$$

in which t represents the daily time of irradiation in minutes, and n is the number of days.

(3) The least rapid germination and minimal growth were attained by normal, non-irradiated seedlings kept under maximal periods of diffuse daylight as transmitted by ordinary window-glass. In the light transmitted there is no appreciable ultraviolet content below 380 mμ; hence, practically speaking, no ultraviolet portion.

(4) The action of diffuse daylight is to inhibit germination of seeds and growth of roots. Since there is a preponderance of greater wavelengths and an absence of ultraviolet radiations in subdued interior daylight, it is evident that the greater wavelengths inhibit (or at least do not stimulate) the germination of seeds and the growth of roots of those seeds which normally germinate and grow underground.

(5) Irradiation by a quartz mercury lamp accelerates the germination of seedlings kept in subdued interior daylight as compared to the germination of normal non-irradiated seeds under similar conditions.

(6) In general, optimal conditions for continuous maximal growth of seedlings kept in interior daylight are attained under irradiation periods of two to three minutes a day.

(7) The stimulus to most rapid germination of